Short-Term Effects of Burning Wyoming Big Sagebrush Steppe in Southeast Oregon

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Abstract

Wyoming big sagebrush (*Artemisia tridentata* subsp. *wyomingensis* [Beetle & A. Young] S.L. Welsh) plant communities of the Intermountain West have been greatly reduced from their historic range as a result of wildfire, agronomic practices, brush control treatments, and weed invasions. The impact of prescribed fall burning Wyoming big sagebrush has not been well quantified. Treatments were sagebrush removed with burning (burned) and sagebrush present (control). Treatments were applied to 0.4-ha plots at 6 sites. Biomass production, vegetation cover, perennial herbaceous vegetation diversity, soil water content, soil inorganic nitrogen (NO_3^-, NH_4^+), total soil nitrogen (N), total soil carbon (C), and soil organic matter (OM) were compared between treatments in the first 2 years postburn. In 2003 and 2004, total (shrub and herbaceous) aboveground annual biomass production was 2.3 and 1.2 times greater, respectively, in the control compared to the burned treatment. In the upper 15 cm of the soil profile, inorganic N concentrations were greater in the burned than control treatment, while soil water, at least in the spring, was greater in the control than burned treatment. Regardless, greater herbaceous aboveground annual production and cover in the burned treatment indicated that resources were more available to herbaceous vegetation in the burned than the control treatment. Exotic annual grasses did not increase with the burn treatment. Our results suggest in some instances that late seral Wyoming big sagebrush plant communities can be prescribed fall burned to increase livestock forage or alter wildlife habitat without exotic annual grass invasion in the first 2 years postburn. However, long-term evaluation at multiple sites across a larger area is needed to better quantify the effects of prescribed fall burning on these communities. Thus, caution is advised because of the value of Wyoming big sagebrush plant communities to wildlife and the threat of invasive plants.

Resumen

Las comunidades vegetales de ''Wyoming big sagebrush'' de (*Artemisia tridentata* subsp. *wyomingensis* [Beetle & A. Young] S.L. Welsh) de los valles del oeste han sido muy reducidas de su rango histórico como resultado del fuego no prescrito, prácticas agronómicas, tratamientos de control de arbustivas e invasión de malezas. El impacto del fuego prescrito en otoño sobre el ''Wyoming big sagebrush'' no ha sido bien cuantificado. Los tratamientos evaluados fueron remoción de ''Sagebrush'' con fuego (quemado) y ''Sagebrush'' presente (control), los cuales se aplicaron en parcelas de 0.4 ha en seis sitios. La producción de biomasa, la cobertura vegetal, la diversidad de la vegetación herbácea perenne, el contenido de agua en el suelo, el nitrógeno inorgánico (NO_3^-, NH_4^+), el nitrógeno total del suelo (N), el carbón total del suelo y la materia orgánica del suelo fueron comparados entre tratamientos en los dos años siguientes a la quema. En el 2003 y 2004 la producción anual de biomasa aérea (herbácea y arbustiva) del tratamiento control fue 2.3 y 1.2 veces mayor, respectivamente, que la del tratamiento de quema. En los 15 cm superiores del perfil del suelo, la concentración de N inorgánico fue mayor en las parcelas de tratamiento con quema que en las del tratamiento control, mientras que el contenido de agua, al menos en la primavera, fue mayor en el tratamiento control que en el de quema. Pese a la mayor biomasa herbácea aérea anual y cobertura vegetal del tratamiento con quema indicaron que los recursos estuvieron más disponibles para la vegetación herbácea en el tratamiento con quema que en el control. Los pastos exóticos anuales no se incrementaron con la quema. Nuestros resultados sugieren que, en algunos casos, las comunidades de ''Wyoming big sagebrush'' en etapas serales finales pueden ser quemadas en forma controlada en otoño para incrementar el forraje para el ganado o alterar el hábitat de la fauna silvestre, sin la invasión de zacates exóticos anuales en los primeros dos años posteriores a la quema. Sin embargo, se necesita la evaluación a largo plazo en múltiples sitios a lo largo de un área mayor, para cuantificar mejor los efectos de la quema prescrita en otoño sobre estas comunidades. Así, se advierte tener precaución debido al valor que las comunidades vegetales de ''Wyoming big sagebrush'' tienen para la fauna silvestre y la amenaza de las plantas invasoras.

Key Words: *Artemisia tridentata* subsp. *wyomingensis*, cover, fire, prescribe burning, production, resource availability

INTRODUCTION

Wyoming big sagebrush (*Artemisia tridentata* subsp. *wyomingensis* [Beetle & A. Young] S.L. Welsh) is the most widely distributed alliance of the big sagebrush (*Artemisia tridentata* Nutt.) complex in the western United States (Küchler 1970; Miller et al. 1994; West and Young 2000). The alliance is considered the least resilient and most susceptible to invasion

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by exotic weeds (Miller and Eddleman 2000). Large areas of this alliance have been converted to cheatgrass (*Bromus tectorum* L.)-dominated grasslands, particularly in the Intermountain West, because of increased fire frequencies (Whisenant 1990; Miller and Eddleman 2000). Further reductions in the alliance have been a result of brush control programs, conversion to croplands, and urbanization (Young et al. 1981; Miller and Eddleman 2000).

The decline of intact Wyoming big sagebrush steppe communities has generated debate regarding the value and risks associated with further brush control treatments, especially prescribed fire. Cheatgrass as well as other weeds have continued to expand and are present even in relatively intact/pristine Wyoming big sagebrush associations (Davies et al. 2006). Land managers are thus uncertain as to the acceptability of using fire as a management tool to shift dominance from Wyoming big sagebrush to desirable herbaceous plants. Of particular concern is the potential for prescribed burning to promote invasion of undesirable exotic annual grasses. Stewart and Hull (1949) and Young and Allen (1997) reported that cheatgrass often rapidly invades lower-elevation sagebrush–bunchgrass communities after fire. Invasion by exotic annual grasses can foster fire return intervals that are too short for reestablishment of sagebrush and are detrimental to desirable herbaceous vegetation (Steward and Hull 1949; Whisenant 1990). The susceptibility of the Wyoming big sagebrush alliance to exotic annual grass invasion necessitates a more thorough quantification of the effects of burning late seral Wyoming big sagebrush communities.

Fire remains the main natural disturbance in the sagebrush ecosystem and shifts communities from shrub to herbaceous dominance (Wright and Bailey 1982). Historical fire return intervals in Wyoming big sagebrush communities were 50–100 years (Wright and Bailey 1982). While a considerable volume of research has addressed impacts of fire on sagebrush communities, the effects of prescribed fire in the Wyoming big sagebrush alliance are limited. In the big sagebrush complex, past work has provided important information on the effects of fire on species and community dynamics (Blaisdell 1953; Wright and Klemmedson 1965; Harniss and Murray 1973; West and Hassan 1985; Akisoji 1988; Wambolt et al. 2001). Most studies have tended to emphasize herbaceous dynamics and ignored the contribution of sagebrush to overall community productivity and structure (Blaisdell 1953; Wright and Klemmendson 1965; West and Hassan 1985). In the one study that measured the contribution of sagebrush to community productivity, Harniss and Murray (1973) reported that for 30 years after burning mountain big sagebrush (*Artemisia tridentata* subsp. *vaseyana* [Rydb.] Beetle) grassland, the unburned controls continued to produce more total aboveground biomass than the burned treatment. In addition, studies have often 1) lacked replication and/or comparable control (unburned) treatments, relying on comparisons of postburn response to preburn conditions (Peek et al. 1979; Humphrey 1984; West and Hassan 1985; West and Yorks 2002), and 2) have evaluated specific species or functional plant guilds or ecological processes without addressing responses in context with overall community response to fire (Blaisdell 1953; Wright and Klemmedson 1965; Blank et al. 1994; Pyle and Crawford 1996; Wrobleski and Kauffman 2003). Furthermore, these studies did not address the potential for exotic grass invasion following prescribed burning of late seral Wyoming big sagebrush communities.

In this study, we evaluated the effects of fall prescribed burning on Wyoming big sagebrush plant community vegetation production, cover, and diversity and soil total C, total N, inorganic N, organic matter (OM), and water content. We hypothesized that removing Wyoming big sagebrush with burning would decrease total plant community production and cover and increase the availability of resources to herbaceous vegetation. We also hypothesized that prescribed burning Wyoming big sagebrush communities would increase exotic annual grass cover and production.

METHODS

Site Description

The study was conducted at the Northern Great Basin Experimental Range (NGBER) in southeastern Oregon (lat 43°47′11″, long 119°69′16″) about 56 km west of Burns, Oregon. The NGBER receives on average 300 mm of precipitation annually. The majority of precipitation comes in the fall, winter, and spring. Crop-year precipitation (October 1–September 30) was 72% and 85% of the long-term average in 2002–2003 and 2003–2004, respectively. The study area is 1 400 m above sea level, and the topography is flat to gentle slopes (slopes $< 2°$). Soils at the study area are a complex of Haploxerolls, Agrixerolls, Durixerolls, and Durargids (Lentz and Simonson 1986). Sites varied in topography, soils, and herbaceous species composition. Wyoming big sagebrush is the dominant shrub (in the unburned areas), and Thurber's needlegrass (*Achnatherum thurberianum* [Piper] Barkworth) or bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh] A. Löve) are the dominant perennial grass depending on site. Idaho fescue (*Festuca idahoensis* Elmer), prairie junegrass (*Koeleria macrantha* [Ledeb.] J.A. Schultes), and squirreltail (*Elymus elymoides* [Raf.] Swezey) were common perennial bunchgrasses across the study area. Common forbs include hawksbeard (*Crepis* sp. L.), curve-pod milkvetch (*Astragalus curvicarpus* [Heller] J.F. Macbr.), tailcup lupine (*Lupinus caudatus* Kellogg), common yarrow (*Achillea millefolium* L.), long-leafed phlox (*Phlox longifolia* Nutt.), desert alyssum (*Alyssum alyssoides* [L.] L.), and little blue-eyed Mary (*Collinsia parviflora* Lindl.).

Experimental Design

A randomized complete block design was used to evaluate the effects of removing Wyoming big sagebrush with burning on vegetation and soil response variables. Six sites with varying topography, soils, and dominant herbaceous species were selected at the NGBER. Each site consisted of two 50×80 m (0.4-ha) plots randomly assigned a burn or unburned (control) treatment. Preburn sampling revealed no differences in vegetation cover or biomass between treatments ($P > 0.05$). Burn treatments were strip head fires applied in October 2002 using a gel-fuel terra torch. Burns were complete across plots receiving the burn treatment. On the days prescribed burning occurred, wind speeds varied between 8 and 20 km $\cdot$ h^{-1}, air temperature was 11°–26°C, and relative humidity varied from

10% to 36%. Fine fuel (herbaceous vegetation) loads were between 350 and 420 $kg \cdot ha^{-1}$, and their moisture content was between 8% and 12%. Response variables were biomass production; vegetation cover; soil total C, N, and OM; soil water; and soil nitrate (NO_3^-) and ammonium (NH_4^+) concentration.

Soil Sampling

Ten 2-cm-diameter soil cores from 0–15- and 15–30-cm depths were collected from each treatment replication at 2-week intervals during the growing season in 2003 and 2004 to measure soil water content in the upper portions of the soil profile. Water content of the soil cores was determined gravimetrically by drying at 100°C to a constant weight.

Total soil N, C, and OM in the upper 15 cm of the soil profiles were determined from 10 samples collected in July of each year from each treatment replicate. Total C and N were determined using a LECO CN 2000 (LECO Corporation, St. Joseph, MI). Organic matter was estimated using the amended Rather method described in Nelson and Sommers (1982). Soil nitrate (NO_3^-) and ammonium (NH_4^+) concentrations were measured from 4 samples from each treatment replicate collected every month during the growing season. Each sample consisted of 5 compiled, 0–15-cm soil cores. Nitrogen fractions were extracted using 2 N KCl solution. The extracted solution was analyzed for NO_3^- and NH_4^+ content by Oregon State University's Central Analytical Lab. Nitrate was analyzed by cation reduction and followed by autoionization and NH_4^+ by autoionization.

Vegetation Sampling

Biomass production was the sum of the current year aboveground shrub and herbaceous production. Herbaceous biomass was determined in late June for the 2 years following treatment by clipping, oven drying, and then weighing the current year's growth from 25 randomly located 1-m^2 frames per treatment replicate.

Sagebrush aboveground biomass production was determined by using allometric relationships between shrub volume and biomass growth for the 2 years separately. These equations were a modification of an equation developed by Rittenhouse and Sneva (1977) on the NGBER. Seventy-five Wyoming big sagebrush plants across the study area but outside the treatment replicates were randomly selected for measurement in July prior to ephemeral leaf drop. Sagebrush canopy volume was determined by measuring 2 perpendicular crown widths and height prior to harvest. The longest crown width was measured first, and then the second width was measured at the center of the first crown width. Harvested sagebrush was dried, and current year's growth (leaves and reproductive stems) was removed and weighed to determine biomass production. Equations were modified each year to correlate canopy volume (cm^3) with annual production: For 2003 sagebrush biomass,

$$\begin{aligned} &\log(\text{Biomass}) = 0.5690 \cdot \log(\text{Volume}) - 1.51 \\ &P < 0.0001, R^2 = 0.7438 \end{aligned} \quad [1]$$

For 2004 sagebrush biomass,

$$\begin{aligned} &\log(\text{Biomass}) = 0.8629 \cdot \log(\text{Volume}) - 4.7666 \\ &P < 0.0001, R^2 = 0.9062 \end{aligned} \quad [2]$$

The canopy volumes of 50 sagebrush plants were measured for each treatment replicate to determine mean canopy volume. Mean canopy values was used in the preceding equations to determine average production per sagebrush plant for each treatment replicate. The average production per sagebrush was multiplied by sagebrush density to provide sagebrush production for each treatment replicate. Density was determined by counting all rooted individuals in five 2×50 m belt transects in each treatment replicate.

Rabbitbrush aboveground production was determined by harvesting one 2×50 m belt transect per treatment replication. Harvested rabbitbrush was dried, and current year's growth was removed and weighed to determine annual production.

Herbaceous cover and perennial herbaceous species density were measured using 120 randomly located 0.2-m^2 frames per treatment replication. Herbaceous cover was visually estimated in each 0.2-m^2 frame. Shrub cover was measured by line intercept (Canfield 1941) along five 50-m transect lines per treatment replicate. Canopy gaps less than 15 cm were included in the shrub cover measurements. Total vegetation cover was the sum of herbaceous and shrub cover. Perennial herbaceous diversity was calculated from density values using the Shannon diversity index (Krebs 1998).

Statistical Analysis

For each year, analysis of variance (ANOVA) was used to test for treatment differences between response variables that were not repeatedly sampled across the growing season. Because of the strong effect differences between the first and second year postburning, years were analyzed separately to simplify presentation and better illustrate treatment effect on response variables. Fisher Protected LSD test was used to test for differences between means. Differences between means were considered significant if *P* values were less than 0.05 ($\alpha = 0.05$). For these analyses, herbaceous cover was grouped into 5 functional groups: tall perennial grass, Sandberg bluegrass (*Poa sandbergii* Vasey), annual grass, perennial forbs, and annual forbs. The purpose of using functional groups is to combine species that respond similarly to environmental perturbation and to reduce data to a simpler form for analysis and presentation (Boyd and Bidwell 2002). Functional groups also permit comparisons among sites with different species composition. Repeated-measures ANOVA was used for variables that involved repeated sampling through the growing seasons (SAS Institute 2001). Between-subject effects were block and treatment. Within-subject effects were sampling date and the interactions of sampling date with the between-subject effects. ANOVA was used to test differences between treatments on individual sampling dates with means separated with a Fisher Protected LSD test. Data were not transformed because assumptions of normality were not violated.

RESULTS

Soil

Nitrate and NH_4^+ concentrations in the upper 15 cm of the soil profile were greater in the burned than control treatment ($P = 0.0014$ and 0.0019, respectively; Fig. 1). Date also had a significant effect on NO_3^- and NH_4^+ concentrations ($P < 0.0001$). The date × treatment interaction was significant for NO_3^- concentrations ($P = 0.0361$). Soil OM, total soil C, and total soil N were not different between treatments in either year of the study ($P > 0.05$; Table 1).

Soil water content in the 0–15-cm depth was generally greater in the control than the burned treatment and varied by date, and the interaction between date and treatment was significant ($P < 0.0001$). Soil water content in the 15–30-cm depth was greater in the control than burned treatment and decreased in both treatments across the growing season ($P = 0.0454$ and $P < 0.0001$, respectively). The interaction between date and treatment was also significant ($P < 0.0001$). Most treatment differences occurred early in the growing season (April and May) of each year. Soil water content tended to be greater at both depths in the control compared to the burned treatment during this period (Figs. 2A and 2B).

Vegetation

Biomass Production. Aboveground biomass production (shrub and herbaceous) was greater in the control than the burned treatment in 2003 and 2004 ($P = 0.0005$ and 0.0467, respectively; Fig. 3). The difference in biomass production between treatments was less in the second postburn year. Herbaceous vegetation production in the burned treatment was greater than in the control treatment in both years of the study ($P = 0.0264$ and 0.0037, respectively). Tall tussock perennial bunchgrass production was greater in the burned than control treatments in 2003 and 2004 ($P = 0.0096$ and 0.0153, respectively; Table 2). Sandberg bluegrass production was less and both annual forb and annual grass production were slightly greater in the burned than control in 2003 ($P < 0.05$) but were not different between treatments in 2004 ($P > 0.05$). Rabbitbrush and perennial forb production did not vary between treatments in either postburning year ($P > 0.05$).

Cover and Diversity. Total vegetation (Fig. 3) and sagebrush (Table 2) cover values were greater in the control than burned treatments in both years of the study ($P < 0.05$). In the first postburn year, total herbaceous, rabbitbrush, and tall tussock perennial grass cover values were greater in the control than the burned treatment ($P < 0.05$). By the second postburn year, herbaceous cover was greater in the burned than control treatments ($P = 0.0326$), and tall tussock perennial grass and rabbitbrush cover did not vary by treatment ($P > 0.05$). Sandberg bluegrass, annual grass, annual forb, and perennial forb cover did not differ between treatments in either year of the study ($P > 0.05$). The Shannon diversity index (Krebs 1998) for the perennial vegetation was not different between the control and the burned treatment in either year of the study ($P > 0.05$; Fig. 4).

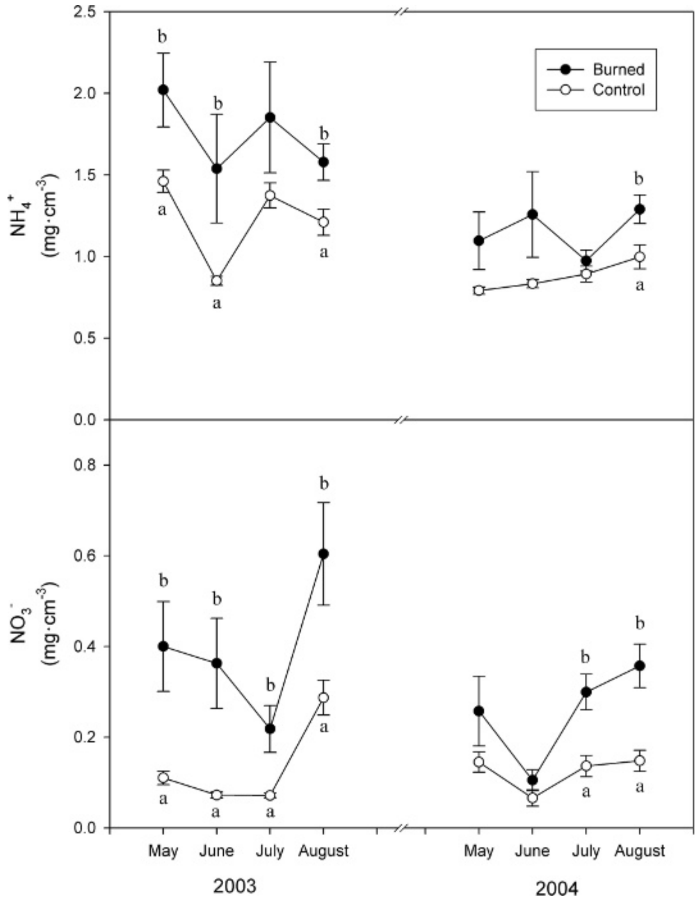

Figure 1. Soil NO_3^- and NH_4^+ concentrations (mean ± standard error) in the upper 15 cm of the soil profile in burned and control treatments in 2003 and 2004. Different lowercase letters indicate differences between treatments on that date from Fisher's LSD tests ($P < 0.05$).

DISCUSSION

The greater total vegetation aboveground biomass production and cover in the control compared to the burned treatment suggest that burned sites did not attain their potential production. Harniss and Murray (1973) reported similar reductions in production when a mountain big sagebrush community was burned. Thirty years after burning, the unburned controls continued to produce more total aboveground biomass annually than burned treatments. This suggests that the reduction in vegetation production from burning Wyoming big sagebrush communities may be a long-term impact. The greater total vegetation cover and biomass production in the control supports our hypothesis that burning would reduce total vegetation production and cover.

In contrast to total vegetation production, herbaceous vegetation production was greater in the burned than control treatment the first year after prescribed burning and more than 2-fold greater the second year, suggesting a greater proportion of resources were available for herbaceous growth. Other authors have reported similar and contrasting herbaceous production responses to sagebrush removal. Similar to our results, Hedrick et al. (1966), Sneva (1972), Harniss and Murray (1973), and Uresk et al. (1976) reported 2- to 3-fold increase in herbaceous production after sagebrush removal. In contrast to our results,

Table 1. Soil organic matter (OM), total C, and total N (mean and standard error [SE]) in the upper 15 cm of the soil profile in burned and control treatments in 2003 and 2004.[1]

		2003		2004	
Soil characteristic	Treatment	Mean	SE	Mean	SE
OM (%)	Burned	1.3	0.1	1.3	0.1
	Control	1.4	0.2	1.3	0.1
Total C (%)	Burned	0.9	0.1	0.8	0.1
	Control	0.9	0.1	0.8	0.1
Total N (%)	Burned	0.08	0.01	0.07	0.05
	Control	0.09	0.01	0.07	0.01

[1]Different lowercase letters indicate difference between treatments in that year ($P < 0.05$). No significant differences were found.

Blaisdell (1953) at the Fremont County sites and Peek et al. (1979) reported no significant changes in herbaceous production after burning sagebrush communities. Conflicting reports of herbaceous response to burning of sagebrush communities may be attributed to differing burn severities, postfire weather, postfire disturbance, herbaceous species composition, and site characteristics. For example, Thurber's needlegrass is negatively impacted by fire (Wright and Klemmedson 1965; Uresk et al. 1976), while bluebunch wheatgrass frequency and basal area may remain unchanged (Peek et al. 1979), or its production may increase after fire (Uresk et al. 1976). With our fall prescribed burn, we observed that limited mortality (based on density counts) of perennial herbaceous vegetation and therefore herbaceous vegetation could respond rapidly to the release from interference/competition with sagebrush.

In our study, herbaceous cover was greater in the burned than control treatment by the second posttreatment year. West and Hassen (1985) reported a similar herbaceous cover response in a Wyoming big sagebrush community in Utah. However, much of their increase in herbaceous cover was cheatgrass, an exotic annual grass, while our increase in cover was from a combination of herbaceous functional groups with no clear major contributor. The lag in herbaceous cover in our burned treatment may be the result of a delayed growth response in herbaceous plants and/or due to residual herbaceous cover being consumed by the fire. Bates et al. (2000) reported a similar lag in herbaceous response to western juniper (*Juniperus occidentalis* Hook.) removal.

Lower soil water content in the upper portion of the soil, especially at the start of the growing season, in the burned compared to the control treatment suggests the loss of

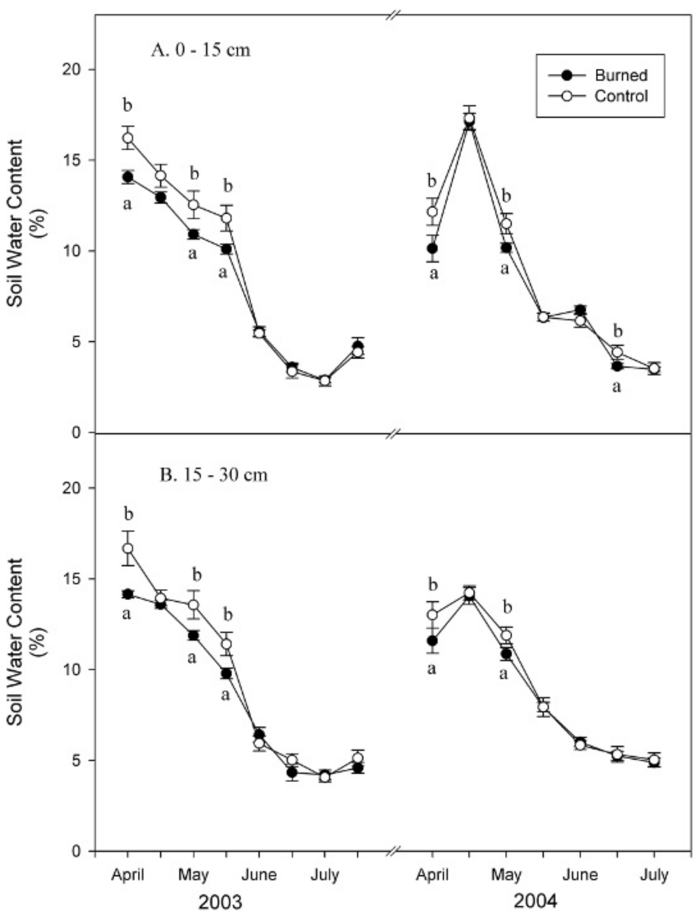

Figure 2. Soil water content (mean ± standard error) in **A**, 0–15-cm and **B**, 15–30-cm depths. Different lowercase letters indicate differences in soil water content between treatments on that sampling date ($P < 0.05$).

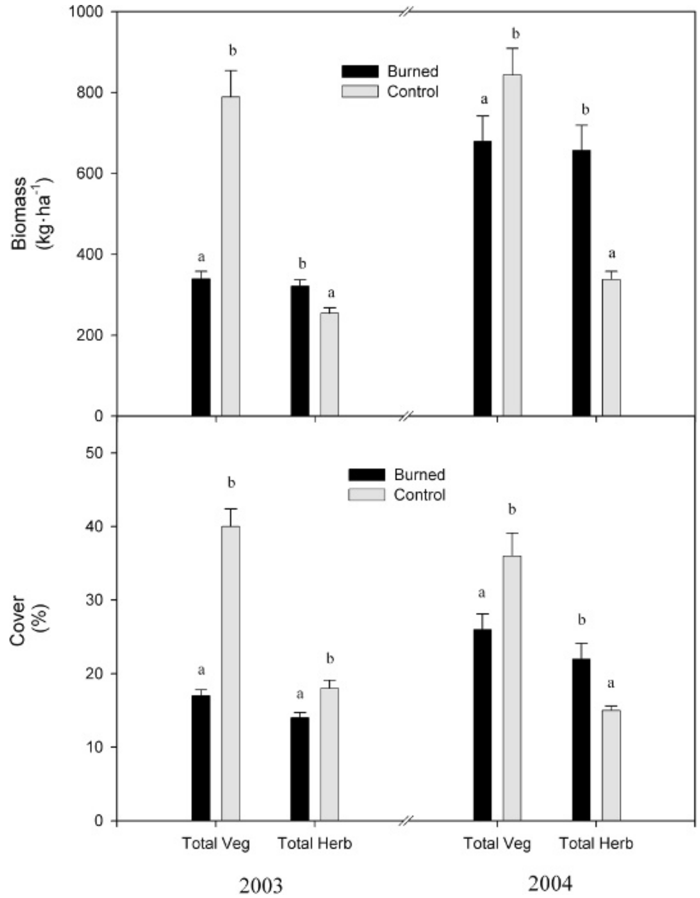

Figure 3. Total vegetation and herbaceous biomass production and cover (mean ± standard error) in the burned and control treatments. Total Veg indicates total vegetation biomass production; Total Herb, total herbaceous biomass production. Different lowercase letters indicate differences between treatments in that year ($P < 0.05$).

Table 2. Vegetation biomass production and cover (mean and standard error [SE]) in the burned and control treatments in 2003 and 2004.[1]

		Biomass				Cover			
		2003 (kg · ha^{-1})		2004 (kg · ha^{-1})		2003 (%)		2004 (%)	
Vegetation	Treatment	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Tall tussock perennial grass	Burned	146 b	15	314 b	33	5.0 a	0.4	7.2	0.8
	Control	107 a	13	148 a	17	7.5 b	0.8	6.0	0.8
Sandberg bluegrass	Burned	35 a	3.6	68	18	6.1	0.3	4.1	0.4
	Control	76 b	8.2	73	12	7.8	0.8	5.9	0.6
Perennial forb	Burned	29	3.9	80	19	2.4	0.2	3.0	0.4
	Control	21	4.0	53	9.0	2.3	0.3	2.1	0.1
Annual grass	Burned	0.89 b	0.28	0.1	0.1	0.01	0.01	0.04	0.02
	Control	0.03 a	0.3	0.3	0.2	0.01	0.01	0.01	0.00
Annual forb	Burned	110 b	19	194	68	1.8	0.3	7.6	3.0
	Control	40 a	11	62	22	1.6	0.6	1.1	0.3
Sagebrush	Burned	0.0 a	0.0	0.0 a	0.0	0.0 a	0.0	0.0 a	0.0
	Control	526 b	60	487 b	62	10 b	1.0	13 b	1.6
Rabbitbrush	Burned	18	3.8	19	3.2	2.1 a	0.3	3.0	0.7
	Control	17	3.3	18	3.5	5.9 b	0.7	5.5	1.2

[1]Different lowercase letters indicate differences between treatments in that year ($P < 0.05$).

sagebrush reduced water capture or increased evapotranspiration. For example, Obrist et al. (2003) reported increased evapotranspiration following wildfire in big sagebrush communities. Similar to our results, Obrist et al. (2004) reported greater soil water content in a control than burned treatment in a big sagebrush community at the start of the growing season. However, because we did not measure water throughout the entire soil profile, we cannot indisputably conclude that water capture was less in the burn than control treatment. Contrary to our results, removal of western juniper (Bates et al. 2000), pinyon-juniper (*Pinus edulis* Engelm—*Juniperus osterosperma* [Torr.] Little; Gifford and Shaw 1973) and Gambel oak (*Quercus gambelii* Nutt.; Marquiss 1972) resulted in increased soil water content. These contradictions with our results may be due to differences in understory vegetation condition, site characteristics, water acquisition patterns, and/or interactions with other plant species. Wyoming big sagebrush is a much smaller plant and generally occupies more arid sites than western juniper, pinyon-juniper, and Gambel oak and may account for the contradiction. Lower soil water content in the burned treatment was probably either due to decreased initial capture of precipitation (especially snow), increased evapotranspiration, or a combination of both. Hutchison (1965) reported that sagebrush communities had higher accumulations of snow than adjacent grasslands. Sturges (1977) reported that snow accumulations were reduced where mountain big sagebrush was removed, compared to where it remained until snow completely covered the sagebrush.

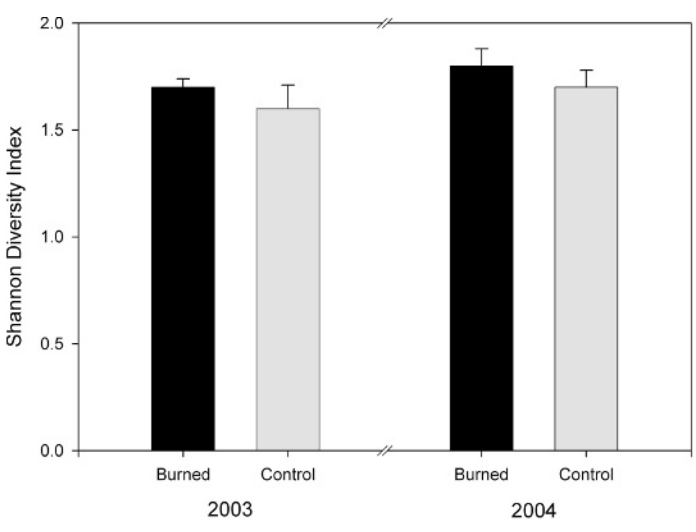

Figure 4. Shannon diversity index for perennial vegetation (mean ± standard error) in the burned and control treatments in 2003 and 2004.

The burn, even with less soil water content at the start of the growing season, had greater herbaceous cover and production compared to the control, indicating that burning increased resource availability to herbaceous vegetation. Higher inorganic nitrogen concentrations in the burned treatment in both postburning years suggest that burning increased resource availability beyond annual consumption. However, the increase in resources from burning did not increase exotic annual grass cover and production and thus does not support our second hypothesis that prescribed burning would increase annual grass production and cover.

The potential excess resources in the burned treatment provide opportunities to establish/increase desired vegetation. Wirth and Pyke (2003) reported that seeding success of 3 perennial forbs was greater in a burned than unburned Wyoming big sagebrush community. The proportion of resources available to herbaceous vegetation increased with burning, and we measured primarily a perennial response to the excess resources. However, there was an increase in *Alyssum* L. sp., an introduced annual plant. *Alyssum* sp. does not appear to significantly hinder recovery of desirable herbaceous vegetation (Bates et al. 2005). Our results indicate that livestock forage can be increased by prescribed fall burning relatively intact, late seral Wyoming big sagebrush communities. However, the risk of weed invasion greatly increases with increased soil resource availability (Sheley et al. 1999a, 1999b; Davis et al. 2000;

Svejcar 2003). Similar to Humphrey (1984), we found no short-term differences in herbaceous perennial vegetation diversity between the burned and control treatments and attributed it to limited plant mortality from the burn treatment. A high vegetation survival of the burn and rapid response by perennials, a limited source of noxious weed propagules, or combinations of these factors may have prevented noxious weed encroachment. Had there been a source of noxious weed propagules near the study site and/or increased herbaceous mortality, noxious weeds may have been more prominent.

MANAGEMENT IMPLICATIONS

Our study is limited to short-term responses of removing sagebrush with prescribed fall burning on late seral Wyoming big sagebrush communities without a readily available source of noxious weed propagules and limited mortality of perennial herbaceous vegetation. Our results elucidate some of the potential impacts of removing sagebrush from plant communities and the need for long-term studies of vegetation production and cover following Wyoming big sagebrush removal with burning. We found that the herbaceous component of late seral Wyoming big sagebrush plant communities can be capable of withstanding disturbance including an occasional prescribed burn. How specific this response is to prescribed burn and site characteristics needs further investigation. Our results imply that fall prescribed burning can be used in some instances in relatively intact, late seral Wyoming big sagebrush communities to increase herbaceous forage and alter wildlife habitat without increasing introduced annual grasses in the first 2 years postburn. However, long-term evaluation is needed to better understand the potential risks and benefits of prescribed burning Wyoming big sagebrush communities. Furthermore, evaluation of prescribed burning Wyoming big sagebrush communities in varying pre- and postclimatic years and across more sites is needed to develop more comprehensive management suggestions. Prescribed burning Wyoming big sagebrush communities should be undertaken with caution because of the threat of exotic annual grasses, the increase in the introduced *Alyssum* sp., and the importance of sagebrush to many wildlife species.

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